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SNAPDRAGON RUST

By GEORGE L. PELTIER

URBANA, ILLINOIS, AUGUST, 1919

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SNAPDRAGON RUST

By GEORGE L. PELTIER, Associate in Floricultural Pathology

INTRODUCTION

The snapdragon (*Antirrhinum majus* Linn.) has been grown for many years as a garden flower. Within the last six or seven years it has also become one of the more important minor crops in commercial greenhouses. As a result, a large number of new varieties suitable for growing under greenhouse conditions have been originated and introduced into all parts of the country.

Coincident with this more intense cultivation under glass, a number of fungous diseases have appeared on the plant. One of these has become serious within the past four years. This is the snapdragon rust (*Puccinia antirrhini* D. & H.), which first became evident in Illinois in 1913 and since that time has caused much loss thruout the state.

HISTORY AND DISTRIBUTION

Snapdragon rust was reported first in this country in 1903, by Blasdale,[1] who, during the summer of 1895, had found it destroying a number of plants growing in the gardens of California. He says: "Since that year the fungus has appeared every season in which an attempt was made to raise this plant, and in every case, destroyed the plants shortly after they had reached the flowering stage. Further observations have shown that the disease is a common one in the region around San Francisco Bay tho I have no knowledge of its occurring elsewhere in the state." Specimens were submitted by Blasdale to Holway and Dietel, and a description of the species was published by them in 1899 under the name of *Puccinia antirrhini*.[2]

Before 1895, however, specimens of rust on snapdragon had been collected a number of times in California, as shown by a letter from Dr. J. C. Arthur: "In my herbarium I have specimens of the rust fungus *P. antirrhini* from the following localities; Santa Cruz, Cal., 1879; Berkeley, Cal., 1897; Ukiah, Cal., 1902; Whittier, Cal., 1909; and Portland, Ore., 1909." No further reports of this rust can be

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Note.—The experimental work of this bulletin was completed in June, 1916. Since September 1, 1916, Dr. Peltier has been Plant Pathologist at the Alabama Experiment Station, Auburn, Ala.

[1]Blasdale, W. C. On a Rust of the Cultivated Snapdragon. Jour. Mycol., 9, 81-82. 1903.

[2]Hedwigia, 36, 298. 1899.

found in the literature up to the outbreak in the vicinity of Chicago in 1913. It is therefore thought that it was probably localized on the west coast for a long period of time.

No mention of the occurrence of snapdragon rust in Europe can be found in European literature, altho this rust was named by a German mycologist from specimens sent to him from the United States.

During the month of July, 1913, the first report of the presence of snapdragon rust on field plants in Illinois was sent to the Illinois Experiment Station from a region near Chicago. By the end of the following month, four new areas of infection had been found in that vicinity. In January, 1914, the writer visited the section and found rust on cuttings and mature plants in a number of greenhouses. Between that time and the fall of 1914, the presence of snapdragon rust was reported by a dozen growers from various parts of the state. Soon thereafter inquiries were received from Indiana and Ohio, and by January, 1915, rust had been found in Wisconsin, Iowa, and Massachusetts. Bailey,[1] in a short note, described this disease from Oregon in 1915. However, Dr. Arthur had had specimens from that state since 1909. Later in the year, rust specimens were received from Michigan thru Dr. Arthur. Only a short time ago (1916) specimens were collected in Alabama by the writer. At the present writing, snapdragon rust is found practically wherever this crop is grown in the greenhouse, and its distribution may be said to be coextensive with the entire area of the United States.

The rapid spread of this rust, especially in the Middle West, is probably related to the fact that young plants may be shipped to all points from infected areas. While it has been impossible to trace directly the origin of the first infection in Illinois, it is thought to have been introduced on cuttings or plants from California.

SYMPTOMS OF THE DISEASE

Snapdragon rust attacks seedlings, cuttings, and mature plants both in the field and in the greenhouse. It is most severe on cuttings and on plants just before blooming time. Leaves, branches, stems, and occasionally seed pods are subject to attacks of this rust. The fungus is limited, as a rule, to the underside of the leaves, while the branches and stems are attacked at any point. The more sheltered points along the stem are, as a rule, infected first.

From eight to fourteen days after a plant has been exposed to rust, light-colored, slightly raised pustules or spots appear. Within a few days these break out into dusty brown masses. Occasionally pustules

[1]Bailey, F. D. Second Bien. Crop Pest and Hort. Rpt., Ore. Agr. Exp. Sta. (1913-14) p. 281. 1915.

are produced on the upper surfaces of the leaves. Under favorable conditions the pustules increase rapidly in number on both the leaves and the stems, causing the death of the plant in a short time (Fig. 1).

FIG. 1.—SNAPDRAGON PLANT KILLED BY RUST

The fungus is able to attack plants at all stages of growth. Cuttings are extremely susceptible, while seedlings are not attacked until several pairs of leaves are formed. The appearance of the rust on cuttings and seedlings is the same as described above for the mature plant.

Rust in the greenhouse may occur thruout the year, but it is especially prevalent during the warmer months, decreasing in winter,

when the temperatures are low and uniform. However, if the temperature of the house is high during the winter, rust will be as severe as in the summer. In the field, rust generally appears in Illinois during the latter part of June or in July and, in severe cases, kills the plants either before or at the time of flowering.

DESCRIPTION OF THE FUNGUS

The life history of the fungus is not completely known, but for the present the organism may be classed as a Hemi form of rust. Only the uredinial and telial stages are known. The uredinial stage is the usual method of propagation both in the field and in the greenhouse. The spores are produced in pulverulent sori, which are generally circular (Fig. 2). On the stems and branches of the host, the sori may become elongate. The urediniospores are spherical to ellipsoidal, varying from 22 to 30 by 21 to 25 microns. They are yellow to dark brown in color, and are borne on short pedicels which are deciduous. The spore walls are echinulate, or warty, and have two and rarely three germ pores. The spores germinate readily in water or on gelatine in from twenty-four to forty-eight hours.

The telial stage does not occur until the latter part of the season; it may be found on the plants both in the field and in the greenhouse. The teliospores are produced either in the uredinia mixed with the urediniospores, or in separate sori on the stems or branches of the plant (Fig. 3). The telia are elongate and quite distinct from the uredinia. The teliospores are thick-walled, two-celled, and somewhat club-shaped. They are a deep brown in color, and bear a persistent pedicel. The spore measurements vary from 36 to 50 by 17 to 26 microns.

All efforts to germinate the teliospores have failed. The spores were subjected by the author to alternate wetting and drying, to high and low temperatures, and to various outdoor conditions thru the winter and the summer. The gelatine plate method was also tried under different conditions, but with no success.

The mycelium of the fungus is localized and does not spread in the tissues of the plant beyond the area first infected.

HOST RELATIONSHIP AND RESISTANCE

In a study of the Scrophulariaceae, to which family the snapdragon belongs, it is found that, with the exception of several native species, all the genera closely related to Antirrhinum have been introduced from Europe. Since specimens of this rust were collected in California as far back as 1879, that state is supposed to be its native habitat. The original host of the fungus is still unknown.

FIG. 2.—LOWER AND UPPER LEAF SURFACES OF SNAPDRAGON SHOWING THE RUST PUSTULES, OR SORI (UREDINIA)

Blasdale[1] in his publication makes the following statements:

"...Thus far only four species of rust inhabiting scrophulariaceous genera have been found in the state. ...

"The two species of Puccinia (*P. wulfeniae* D. & H. on *Wulfenia cordata* and *P. rufescens* D. & H. on *Pedicularis semiborata*) present decidedly different characters from those of the species to which the snapdragon disease is due. ... The first mentioned species has been found but once in the Bay region and then only in small amounts, the latter is known only from the Sierra Nevada mountains. ...

"Attempts to infect various other species of scrophulariaceous genera with the disease have been successful in three instances only. During the past season it was found that the plants of the native *Antirrhinum vagans*, grown from seed, were attacked with nearly the same degree of destructiveness as the cultivated species. Also plants of *Linaria reticulata* and *L. amethystina* were attacked by the disease but to a much less degree than the other species. ...

"Presumably then the snapdragon rust originated on the wild form of Antirrhinum but thus far the disease has never been found on the plants growing spontaneously, though diligent search has been made for it whenever the opportunity was offered.

"The only alternative is to assume that it is a case of adaption of a species from a host plant belonging to a different order."

[1] *Loc. cit.*

A number of cross-inoculations with several species of Antirrhinum, a large number of commercial varieties of *A. majus* Linn., *Linaria vulgaris* Mill. (the common butter-and-eggs), and a number of species and commercial varieties of Linaria, was attempted by the author for two seasons, but with little success. No rust infection was obtained on *Linaria vulgaris* or on any other species or commercial varieties of Linaria. This was true also of Antirrhinum species, with the exception of *A. majus* and its numerous varieties. On the latter, infection was very severe. In one case flaking occurred on *A. maurandioides* Gray, a climbing plant native to the Southwest, several urediniospores being produced. All the inoculations were made with urediniospores under the most favorable conditions. The rust of snapdragons appears, then, to be closely limited to *Antirrhinum majus* and its varieties.

These results substantiate, in part, those obtained by Blasdale, and in all probability the native host of this rust is to be found outside of the Scrophulariaceae. There is of course the possibility of the rust having been introduced into California on some plant from Asia.

Finding that the rust was apparently confined to *A. majus* and its varieties, the author conducted inoculation tests on some sixty or more varieties in the greenhouse and in the field, over a period of three

FIG. 3.—ELONGATE RUST PUSTULES, OR SORI (TELIA), ON STEMS OF SNAPDRAGON

years. These varieties represented practically all the different types offered by the American seedsmen. All degrees of variations were represented, in thickness of the epidermis, in the presence of a cutinized epidermis, and in protective appendages, such as hairs, etc. The results of these tests indicated that all varieties were equally susceptible to the rust. Infection took place in from nine to sixteen days after inoculation.

PREVENTION AND CONTROL OF SNAPDRAGON RUST

Unfortunately little or no progress has been made toward the development of rust-resistant varieties of snapdragon, so that the elimination of the fungus by this method is, at the present time, out of the question. The following experiments with fungicides also show rather conclusively the ineffectiveness of spraying as a means of controlling the rust. Thru the adoption of certain cultural methods, however, the possibility of at least partial control in the greenhouse is assured, while the disease can be avoided, or eliminated in time, by the propagation of plants from seed.

EXPERIMENTS WITH FUNGICIDES

During the first week in June, 1915, 640 snapdragons, representing forty varieties, were transplanted from four-inch pots into the field. About two weeks were allowed to elapse before the first spraying was started. By this time the plants had begun to put out new growth and were fairly well established. A number of the plants were infected at the time of transplanting, and by the end of the first two weeks frequent rains had brought about infection on practically all of them. The plants were divided into four equal lots. One set was sprayed thoroly with Bordeaux (4-4-50); a second, with ammoniacal copper carbonate; and the third set, with Fungine (1-30), a prepared fungicide containing potassium sulfid. The fourth lot served as a check.

Each fungicide was applied on the following dates: June 6 and 26; July 2, 9, 14, and 20. A complete record of every plant was made after the last application. All the plants had become badly rusted and many were completely killed. The sprayed plants were in as bad condition as those in the check plot. Judging from the result of this experiment, snapdragon rust once it has made its appearance on the plants cannot be controlled in the field by the fungicides used.

In the fall of 1915 spraying experiments were started in each of two houses. A north bench, divided into ten five-foot sections, was used in each case. Between the sections a double cheesecloth curtain, fastened on frames four feet high, was set up to eliminate as much as possible the spread of rust from section to section. Each section

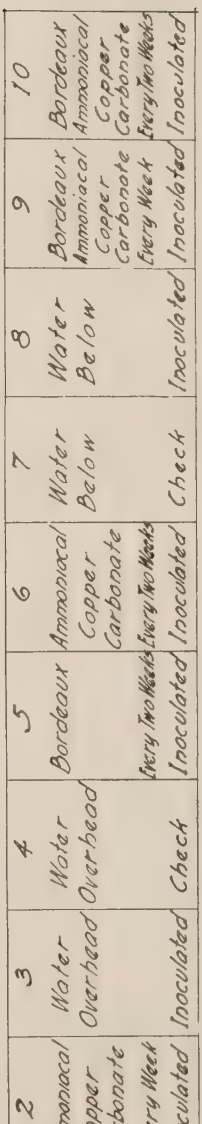


FIG. 4.—ARRANGEMENT OF SECTIONS IN SPRAYING EXPERIMENTS FOR CONTROL OF SNAPDRAGON RUST IN THE GREENHOUSE

was planted to twenty snapdragons representing five varieties; namely, Phelp's White, Mixed (seed obtained from plants killed by rust in the field during the summer), Giant Lilac, Buxton's Pink, and Nelrose. Four plants of each variety were set in a row across the bench, twelve inches being allowed between the plants. These plants had been grown from seed in the usual manner. When benched on November 17, 1915, they were healthy and free from rust. Unless otherwise stated, all sections received the same treatment as is used in growing snapdragons commercially.

Beginning on November 20 each section was treated as shown in Fig. 4. Where the combined treatment was used, Bordeaux was applied until the spikes developed and then ammoniacal copper carbonate was substituted for the remainder of the season. The latter was used to avoid discoloring the flowers with the Bordeaux.

For several weeks the sections in House No. 1 marked "inoculated" were artificially infected with rust spores for two or three days after each spraying. In House No. 2 natural infection was depended on, that house having been used the previous season in the rust work.

In House No. 1 no infection occurred in any of the sections until January 29, 1916, ten weeks after the plants were first inoculated. The section in which the plants were watered overhead (syringed) and inoculated, was the first section to develop signs of the rust. This section was followed by the one in which the plants were watered from overhead and not inoculated. By February 26 rust was present in all the sections but one. The last section to become infected was the one in which the water was applied to the soil only. Rust was first observed in that section on March 25, four months after the experiment was started.

The results in House No. 2 were somewhat similar. Rust first appeared on February 5 on the plants in the two sections watered overhead, followed on February 19 by the sections watered from below, the sections sprayed every two weeks with Bordeaux and ammoniacal

copper carbonate, and the sections where the combined treatments were applied every week and at two-week intervals. By March 25 all the plants in the remaining sections were rusted. Apparently the rust appeared later under natural infection than under artificial infection; also some of the treatments were more effective in the sections naturally infected.

A final examination of each plant was made during the latter part of May. In making these examinations, the plant showing the largest amount of leaf rust was used as a standard (100 percent) by which to measure the amount of leaf infection on all other plants. The same method was used for stem infection. After the percentage of leaf and stem infection was determined for each plant, the results were tabulated from the standpoint of both the treatments and the varieties. No striking differences were shown in the susceptibility of any of the varieties. In the following table is given the average percentage of leaf and stem infection for each section in each house. In comparing the results, it should be remembered that in House No. 2 natural infection was depended on.

RESULTS OF SPRAYING EXPERIMENT FOR SNAPDRAGON RUST, IN GREENHOUSE: 1915-16

Section	Treatment	Average percentage of infection			
		House No. 1		House No. 2	
		Leaf	Stem	Leaf	Stem
1	Bordeaux every week	55	15	45	0
2	Ammoniacal copper carbonate every week	66	15	47	0
3	Water overhead	80	42	57	27
4	Water overhead—check	78	33	36	4
5	Bordeaux every two weeks	48	18	13	0
6	Ammoniacal copper carbonate every two weeks	62	26	41	1
7	Water below	53	25	31	0
8	Water below—check	48	6	57	17
9	Bordeaux and ammoniacal copper carbonate every week	46	1	42	0
10	Bordeaux and ammoniacal copper carbonate every two weeks	56	14	68	16

The results in House No. 1 show that all the spraying treatments were ineffective in the control of the rust. The largest amount of infection naturally occurred in those sections in which the plants were watered from overhead (syringed). Where only the soil in the sections was watered the percentage of leaf infection was lower than in any of the sprayed sections except one. In other words, this treatment was just as effective in the control of rust as were Bordeaux and ammoniacal copper carbonate when applied every week.

In House No. 2 practically the same results were obtained. On the whole, however, the infection in this house was not so great as in House No. 1, nor was it so uniform owing to the fact that natural infection was depended upon. In the last three sections infection was more severe than in the other sections of the house because rust experiments had been carried on in the bench adjacent to these during the previous season. However, the plants in all the sprayed sections had an abundance of rust. As in House No. 1 the greatest amount was found on the plants in the sections watered from overhead. Decidedly less stem rust occurred in House No. 2 than in House No. 1.

From the results of these experiments, then, it may be concluded that the fungicides used will neither prevent, check, nor control snapdragon rust in the greenhouse; it can be further concluded that by watering the soil only, in the bench, and avoiding all syringing, the disease can be held in check better than by the use of fungicides.

EFFECT OF CULTURAL METHODS

In making a study of the fungous diseases of plants, a study of the host plant and the methods used in its culture is as necessary as is a knowledge of the fungus causing the disease. In many cases, by modifying the cultural methods in use, attacks of fungi can be to some extent avoided or prevented. This is all the more important in the case of the snapdragon, which in the open is a half-hardy perennial. In the greenhouse, the external conditions under which the plants are growing, such as temperature and moisture, may affect the plants in such a way as to make them more susceptible to disease. The stems of snapdragon plants in the greenhouse are, for example, much more succulent than those grown outside and they do not harden as in the open. A succulent stem is more susceptible to snapdragon rust than a hard, firm stem.

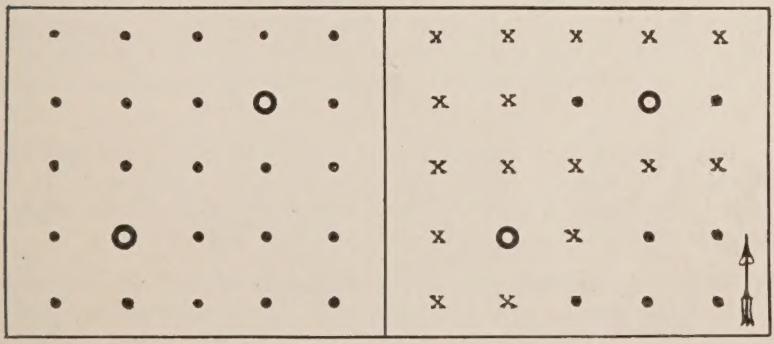
Cuttings from Infected Plants.—Cuttings are extremely susceptible to rust, both in the cutting bench and after they are potted. The author has seen three thousand cuttings infected with rust and killed in three weeks time. He has also seen a large number of young plants lost just after being potted. Great care, therefore, must be exercised to prevent infection of cuttings. Such infection may be initiated in the cutting bench either by the introduction of spores or by the use of cuttings made from infected plants. A single diseased cutting may mean the loss of nearly all the cuttings later on. It is extremely difficult to select cuttings free from the disease in a house or field where the rust has been prevalent. Certain plants may appear to be free from rust, but cuttings from these plants may lead to disappointment, for the pustules, which give the first appearance of the disease,

do not become evident until some time after infection has taken place. Cuttings from such plants carrying the disease in the incipient stage may thus become centers of infection for an entire bench of cuttings.

Syringing.—Two important conditions favorable to the development and dissemination of the rust in a bench of cuttings are shade and syringing. For a week or ten days after the cuttings are placed in the sand the usual procedure is to syringe the cuttings frequently and keep them under shade in bright weather. Such conditions are most favorable for the germination of the rust spores in that the necessary degree of moisture is maintained. The fungus will mature rapidly, new spores will be produced, and soon the entire lot of cuttings will show infection.

Syringing is practiced also for the control of small insects, such as the red spider. When syringing is practiced in an infected house, the development and spread of the rust is very rapid. To illustrate this point the following experiment was carried out during the season of 1914-15.

Two sets of twenty-three healthy snapdragon plants growing in four-inch pots were arranged eight feet apart on a greenhouse bench. Two badly rusted plants were set in each section in the positions shown by the circles in Fig. 5. In the first set only the soil in the pots was watered. Care was taken not to wet or disturb the foliage. In the second section the soil in the pots was watered as in the first section, but in addition the plants were given a good syringing with a strong water pressure. The syringing was done from one side of the bench, the direction of the current being indicated by the arrow in Fig. 5.



SECTION 1—WATERED UNDERNEATH SECTION 2—SYRINGED

FIG. 5.—EFFECT OF UNDERNEATH AND OVERHEAD WATERING (SYRINGING) ON DEVELOPMENT AND SPREAD OF SNAPDRAGON RUST; 1914-15

The open circle shows the location of the infected plants placed in the bench. The arrow indicates the direction of watering. The cross shows the plants to which infection was carried.

The experiment was discontinued at the end of sixty days and the plants carefully examined for rust. Each plant infected with rust is represented by a cross. Where water was applied to the soil in the pots without syringing, no infection was found. Where syringing was practiced, sixteen plants, or 69.5 percent, were badly infected with rust. Note that the infected plants are in the position where the rust spores were carried by the water from the infected plants.

Syringing, then, not only favors the development of the rust, but it actually carries and spreads the spores to other plants. Where no syringing is done, the rust spores are less likely to germinate, and consequently less infection results.

Under the spraying experiments reported on pages 541-44, the sections in which the soil only was watered, with no syringing, were the last to become infected and showed the smallest percentage of infection. In those sections where overhead watering was practiced, the plants were the first to become infected and showed the highest percentage of infection.

Form of Plant.—The form of the plant is an important factor in the destructiveness of the rust. The ideal plant should fork low and not have more than five or six stems. Such a plant is less liable to destruction by the rust than a bushy plant with dense foliage. This of course is true where syringing is practiced. The reason is obvious; the plant with few stems growing out from the center will dry off very quickly after syringing, while several days may be necessary for the center of a bushy plant to dry out. As the rust spores require from twenty-four to forty-eight hours for germination, the evaporation of the water during the day will kill the germinating spores and so prevent infection. Where the water does not evaporate for several days, rust will invariably develop. The habit of the plant, then, is of some importance in checking the spread of rust in the greenhouse.

Destroying Infected Leaves.—An attempt to control the rust by pinching off and destroying the infected leaves was practically a total failure, altho a partial success was obtained during the winter months when the development and spread of rust was slow.

Seed.—Experiments were also conducted in an effort to determine whether rust can be carried on the seed. Seed representing thirty-six commercial varieties was obtained from various sources. From this seed about eighteen hundred plants were grown to maturity without a single pustule of rust developing. Again, seed gathered from badly infected plants in the field and in the greenhouse, sown and grown in the usual manner, developed no rust whatsoever, even tho seed was taken from pods on which rust pustules were present.

It can be safely stated that rust is not carried on seed nor propagated by seed. Altho seeds of the snapdragon do not carry the rust from season to season, and seedlings are not easily susceptible to infection, propagation by seeds has a disadvantage in the fact that few strains are fixed, and selection must be practiced in order to have desirable strains. However, the use of seedlings makes it possible to eliminate the rust. If in a rust-infected house or field all infected plants are burned, and after a lapse of a year or two a new beginning with seedlings is made, clean, healthy plants, will result. From such plants good strains can then be developed by means of careful selection.

Rust in the Field.—The florist plants but few snapdragons in the field, altho he may use young plants in the spring for bedding and border work. In fact, practically all snapdragons grown outside are used in this way. Most of the plants are grown from seed and planted out the latter part of May.

Rust in the field may be traced to two sources—rusted plants of the previous season and the use of infected plants. Experiments have shown that the urediniospores can winter over in the vicinity of Urbana, Illinois. In the planning of the beds and borders, especially on the large estates where the greater number of plants are used, changes are made each season and often snapdragons are omitted from the scheme of planting. So few of these plants are used in decorative and landscape work that the spread of rust from one planting to another is almost negligible. In the majority of cases rust is propagated from season to season in the greenhouse and is carried from there to the field. During favorable seasons in the field, rust will completely kill the plants just before blooming time and by fall the whole planting will be dead. It is very important, then, to use only clean plants in the field; which means that the grower must eliminate entirely the rust from the greenhouse before he can be sure that he is using clean stock in the field.

A few growers raise snapdragons thruout the year, but the majority prefer to plant in August for an early winter crop or else reserve them to follow the early or midseason chrysanthemums. Plants are used from both seeds and cuttings. If plants are rusted when benched, they rarely reach maturity or produce salable spikes. When clean plants are benched, little or no rust develops until in the early spring, when it spreads very rapidly. Temperature is of importance in the development of rust; it has been observed that the spread of rust is checked in the house by a uniformly low temperature. High temperatures are very favorable to the rapid spread of the fungus.

SUMMARY

1. Snapdragon rust, which has been known since 1879 in California, was introduced into Illinois about 1913, and in a short time spread rapidly thruout the United States. The rapid spread of the rust was probably due to the shipment of young plants from infected areas.

2. The disease attacks plants at all stages of growth—from cuttings and seedlings to mature plants. It becomes evident on leaves, branches, stems, and occasionally on seed pods, both in the field and in the greenhouse.

3. The cause of the disease is a fungus known as *Puccinia antirrhini* D. & H. Infection occurs, so far as is known, only thru the urediniospores.

4. From the results of the inoculation experiments, the rust appears to be limited to *Antirrhinum majus* Linn. and its varieties. All varieties of this species are equally susceptible.

5. The use of Bordeaux, ammoniacal copper carbonate, or Fungine can neither prevent, check, nor control snapdragon rust in the field or in the greenhouse.

6. The use of snapdragon cuttings or seedlings where rust is present may mean a complete failure of the crop.

7. Syringing is an important factor in the prevalence of the rust in the greenhouse. It is a means of dissemination of the spores, and it produces conditions favorable for the germination of the spores and the rapid infection of the plants.

8. Watering the plants from below only, so as to avoid wetting the foliage, is a means of checking the rust.

9. Snapdragon rust is not carried on the seeds. The disease can therefore be avoided, or eliminated in time, by the propagation of plants from seed.

RECOMMENDATIONS

Snapdragon rust may be partially controlled in the greenhouse by giving attention to cultural methods. Growing the plants under the best conditions, in a clean, well-kept, and well-ventilated house will check to some extent the dissemination of the disease. Plants should not be syringed if this can possibly be avoided, but instead the soil only should receive water when the plants require it.

In order to eliminate the rust, it is recommended that all infected material be destroyed, the house cleansed, and after a year or two new stock secured which is free from rust. The latter may be secured by the use of seed and the practice of selection.